APPENDIX C

METHODOLOGY FOR DETERMINING COST EFFECTIVENESS

This appendix is an excerpt from the Board approved
2008 Carl Moyer Program Guidelines Part IV Appendixes

The complete Carl Moyer Program Document including all appendices can be found at:
http://www.arb.ca.gov/msprog/moyer/2008guideline_updates.htm

TABLES FOR EMISSION REDUCTION AND COST-EFFECTIVENESS CALCULATIONS

This appendix presents tables summarizing the data and instructions needed to calculate the emission reductions and cost-effectiveness of potential locomotive demonstration project, examples provided below are for reference only and do not constitute additional demonstration project types or categories nor do Carl Moyer funding amounts limit the amount of funding that may be available for demonstration projects.

Table B-1
Capital Recovery Factors (CRF) for Various Project Life
At Four Percent Discount Rate

Project Life	CRF
1*	1.040
2*	0.530
3	0.360
4	0.275
5	0.225
6	0.191
7	0.167
8	0.149
9	0.134
10	0.123
11	0.114
12	0.107
13	0.100
14	0.095
15	0.090
16	0.086
17	0.082
18	0.079
19	0.076
20	0.074

Table B-13
Controlled Off-Road Diesel Engines
Emission Factors (g/bhp-hr)

Tier	Horsepower	NOx	ROG	PM10
1	25 – 49	5.26	1.74	0.480
	50 – 119	6.54	1.19	0.552
	120 – 174	6.54	0.82	0.274
	175 +	5.93	0.38	0.108
2	25 – 49	4.63	0.29	0.280
	50 – 119	4.75	0.23	0.192
	120 – 174	4.17	0.19	0.128
	175 – 250	4.15	0.12	0.088
	251+	3.79	0.12	0.088
3	50 – 120	2.74	0.12	0.160
	121 – 750	2.32	0.12	0.112
4 Interim	25 – 49	4.55	0.12	0.128
	50 – 120	2.40	0.11	0.056
	121 – 174	2.15	0.11	0.008
	175 – 750	1.29	0.08	0.008
	>750	2.24	0.12	0.048
4 Final	25 – 49	2.75	0.12	0.008
	50 – 120	1.33	0.08	0.008
	121 – 750	0.26	0.06	0.008
	>750	2.24	0.06	0.016

Emission factors were converted using the ultra low-sulfur diesel fuel correction factors listed in Table B-28.

Table B-18a
Locomotive Emission Factors (g/bhp-hr)
Based on 1998 Federal Standards

Engine Model Year	Type	NOx[a]	ROG[b]	PM10[a]
Pre-1973	Line-haul and Passenger	12.22	0.51	0.275
	Switcher	16.36	1.06	0.378
1973-2001 Tier 0	Line-haul and Passenger	8.08	0.51	0.275
	Switcher	11.84	1.06	0.378
2002-2004 Tier 1	Line-haul and Passenger	6.30	0.49	0.275
	Switcher	9.31	1.06	0.370
2005-2011 Tier 2	Line-haul and Passenger	4.65	0.27	0.155
	Switcher	6.86	0.54	0.163

These factors are to be used for the project baseline emissions if the baseline locomotive is certified or required to be certified to the 1998 federal locomotive remanufacture standards, and for the reduced emission locomotive if the project locomotive is remanufactured to these 1998 standards. Factors are based upon Regulatory Impact Analysis: Final U.S. EPA Locomotive Regulation (2008).
a - NOx and PM10 emission factors have been adjusted by a factor of 0.94 and 0.86, respectively, to account for use of California ultra-low sulfur diesel fuel.
b - ROG = HC * 1.053

Table B-18b
Locomotive Emission Factors (g/bhp-hr)
Based on 2008 Federal Standards

Engine Model Year	Type	NOx[a]	ROG[b]	PM10[a]
1973-2001 Tier 0+	Line-haul and Passenger	6.77	0.32	0.172
	Switcher	9.98	0.60	0.198
2002-2004 Tier 1+	Line-haul and Passenger	6.30	0.31	0.172
	Switcher	9.31	0.60	0.198
2005-2011 Tier 2+	Line-haul and Passenger	4.65	0.14	0.069
	Switcher	6.86	0.27	0.095
2011-2014 Tier 3	Line-haul and Passenger	4.65	0.14	0.069
	Switcher	5.07	0.27	0.069

These factors are to be used for the project baseline emissions if the baseline locomotive is certified or required to be certified to the new (2008) federal locomotive remanufacture standards, and for the reduced emission locomotive if the project locomotive is remanufactured to the new standards or meets Tier 3 standards. Factors are based upon Regulatory Impact Analysis: Final U.S. EPA Locomotive Regulation (2008).
a - NOx and PM10 emission factors have been adjusted by a factor of 0.94 and 0.86, respectively, to account for use of California ultra-low sulfur diesel fuel.
b - ROG = HC * 1.053

If a Tier 4 emission factor is needed for your AQIP demonstration project cost effectiveness calculation please see US EPA Technical Highlight document EPA-420-F-09-025 April 2009 for values. See footnote "b" above from Table B-18b

REFERENCES

The information in these tables has already been incorporated into the preceding emission factor tables. These tables are included for informational purposes.

Table B-26
Pollutant Fractions
NOx+NMHC Standards

Diesel Engines		Alternative Fuel Engines	
NOx	NMHC	NOx	NMHC
0.95	0.05	0.80	0.20

Table B-28
Fuel Correction Factors
Off-Road Diesel Engines

Model Year	NOx	PM10
Pre-Tier 1	0.930	0.720
Tier 1+	0.948	0.800

Example cost effectiveness calculations are show below.

General Cost-Effectiveness Calculations

The cost-effectiveness of a project is determined by dividing the annual cost of the potential project by the annual weighted surplus emission reductions that will be achieved by the project as shown in formula C-1 below.

Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton):

$$\frac{\textit{Annualized Cost (\$/yr)}}{\textit{Annual Weighted Surplus Emission Reductions (tons/yr)}}$$

Descriptions on how to calculate annual emission reductions and annualized cost are provided in the following sections.

A. Calculating the Annual Weighted Surplus Emission Reductions

Annual weighted emission reductions are estimated by taking the sum of the project's annual surplus pollutant reductions following formula C-2 below. This will allow projects that reduce one, two, or all three of the covered pollutants to be evaluated for eligibility to receive Carl Moyer Program funding. While NOx and ROG emissions are given equal weight; emissions of combustion PM10 (such as diesel exhaust PM10 emissions) have been identified as a toxic air contaminant and thus carry a greater weight in the calculation.

Formula C-2: Annual Weighted Surplus Emission Reductions:

*NOx reductions (tons/yr) + ROG reductions (tons/yr) + [20 * (PM10 reductions (tons/yr)]*

The result of formula C-2 is used to complete formula C-1 to determine the cost-effectiveness of surplus emission reductions.

In order to determine the annual surplus emission reductions by pollutant, formula C-3 below must be completed for each pollutant (NOx, ROG, and PM10), for the baseline technology and the reduced technology, totaling up to 6 calculations:

1. Annual emissions of NOx for the baseline technology
2. Annual emissions of NOx for the reduced technology
3. Annual emissions of ROG for the baseline technology
4. Annual emissions of ROG for the reduced technology
5. Annual emissions of PM10 for the baseline technology
6. Annual emissions of PM10 for the reduced technology

These calculations are completed for each pollutant by multiplying the engine emission factor or converted emission standard (found in Appendix B) by the annual activity level and by other adjustment factors as specified for the calculation methodologies presented.

The **baseline technology** is the technology applied under normal business practices, such as, an engine certified by ARB to the current emission standards for new purchases; or the existing engine in a vehicle or equipment for repowers and retrofits.

The **reduced technology** is the newer technology used by the applicant to obtain surplus emission reductions. The newer technology may be one of the following:

- For a new purchase it would be the engine certified by ARB to reduce NOx emissions by at least 30 percent less than the current NOx emission standard, or certified by ARB to the optional NOx or NOx+NMHC emission standard. Locomotive and marine vessel new purchases have slightly different criteria. Please see the specific source category cost-effectiveness criteria for more information.
- For a repower it would be the replacement engine certified by ARB (for locomotives and marine vessels it would be EPA verified) to a minimum of 15 percent less than the NOx emissions from the baseline technology (existing engine).
- For a NOx retrofit it would be an ARB-verified retrofit technology that will reduce NOx emissions by a minimum of 15 percent from the NOx emissions of the baseline technology.
- For a PM retrofit it would be the ARB-verified diesel emission control strategy (DECS) that reduces PM emissions as level 1 (25 percent reduction), level 2 (50 percent reduction), or level 3 (85 percent reduction).

Since the emission factor or converted standard is given in units of grams, a conversion from grams to tons is also required, as described in formula C-3 below.

Formula C-3: Estimated Annual Emissions by Pollutant (tons/yr):

Emission Factor or Converted Emission Standard (g/bhp-hr) * Annual Activity * Adjustment Factor(s) * Percent Operation in CA * ton/907,200g

The Carl Moyer Program allows the emissions reductions from a project to be calculated using the following activity factors on an annual basis:

- *Hours of operation,*
- *Fuel consumption, or*
- *Miles traveled.*

1. Calculating Annual Emissions Based on Fuel Consumption

When annual fuel consumption is used for determining emission reductions, the equipment activity level must be based on annual fuel usage within California provided by the applicant. Fuel records must be maintained by the engine owner as described in the relative source category chapter for additional information on this topic.

An energy consumption factor (ECF) must be used to convert emissions given in g/bhp-hr to units of grams of emissions per gallon of fuel used (g/gal). The ECF is a number that combines the effects of engine efficiency and the energy content of the fuel used in that engine into an approximation of the amount of work output by an engine for each unit of fuel consumed. The ECF is found in Table B-25 in Appendix B. Formula C-6 below is the formula for calculating annual emissions based on annual fuel consumed.

Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr):

*Emission Factor or Converted Emission Standard (g/bhp-hr) * ECF (hp-hr/gal) * Activity (gal/yr) * Percent Operation in CA * ton/907,200g*

For on-road projects, if the emission factor is in g/mile, a unit conversion factor (bhp-hr/mile) found in Table B-8 in Appendix B must be used to convert from g/mile to g/bhp-hr. This is completed by dividing the emission factor (g/mile) by the conversion factor (bhp-hr/mile) resulting in (g/bhp-hr). Formula C-7 below is used to calculate annual emissions for fuel based on-road calculations.

Formula C-7: Estimated Annual Emissions based on Fuel Consumed using On-Road Emission Factors (tons/yr):

*[On-Road Emission Factor (g/mile)/Unit Conversion Factor (bhp-hr/mile)] * ECF (hp-hr/gal) * Activity (gal/yr) * Percent Operation in CA * ton/907,200g*

2. Calculating Annual Emissions Based on Annual Miles Traveled

Calculations based on annual miles traveled are only used for on-road projects. Mileage records must be maintained by the engine owner as described in Part 1, Chapter 3: On-road Heavy-Duty Vehicles.

<u>Calculations Using Emission Factors:</u> There is no conversion since the emission factors for on-road projects provided are given in units of g/mile. Formula C-8 describes the method for calculating pollutant emissions based on emission factors and miles traveled.

Formula C-8: Estimated Annual Emissions based on Mileage using Emission Factors (tons/yr):

*Emission Factor (g/mile) * Activity (miles/yr) * Percent Operation in CA * ton/907,200g*

<u>Calculating Annual Emissions Based on Converted Standards</u>**:** The unit conversion factor found in Table B-8 in Appendix B is used to convert the units of the converted emission standard (g/bhp-hr) to g/mile. Formula C-9 describes the method for calculating pollutant emissions using converted emission standards.

Formula C-9: Estimated Annual Emissions based on Mileage using Converted Emission Standards (tons/yr):

*Converted Emission Standard (g/bhp-hr) * Unit Conversion (bhp-hr/mile) * Activity (miles/yr) * Percent Operation in CA * ton/907,200g*

3. Calculating Annual Surplus Emission Reductions by Pollutant

The final step in this portion of the calculations is to determine the annual surplus emission reductions by pollutant. For new purchases and repower projects, subtract the annual emissions for the reduced technology from the annual emissions for the baseline technology following formula C-10 below.

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases:

Annual Emissions for the Baseline Technology –
Annual Emissions for the Reduced Technology

For retrofits, multiply the baseline technology pollutant emissions by the percent of emission reductions that the ARB-verified reduced technology is verified to following formula C-11 below.

Formula C-11: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Retrofits:

*Annual Emissions for the Baseline Technology **
Reduced Technology Verification Percent

Calculations must be done for each pollutant, NOx, PM10, and ROG, giving a total of three calculations.

For fleet modernization projects the baseline will be the newer vehicle emissions.

The annual surplus emission reductions by pollutant would be used in Formula C-2 to calculate the annual surplus emission reductions.

Determining the Annualized Cost

Annualized cost is the amortization of the one-time incentive grant amount for the life of the project to yield an estimated annual cost. The annualized cost is calculated by multiplying the incremental cost by the capital recovery factor (CRF). The resulting annualized cost is used to complete formula C-12 to determine the cost-effectiveness of surplus emission reductions.

Formula C-12: Annualized Cost ($):

*CRF * incremental cost ($)*

1. Calculating the CRF

The CRF is the level of earnings reasonably expected by investing state funds in various financial instruments over the length of a Carl Moyer Program project.
The CRF uses an interest rate and project life to determine the rate at which earnings could reasonably be expected if the same funds were invested over a length of time equaling the project life. The CRF is calculated following formula C-13 below.

Formula C-13: Capitol Recovery Factor (CRF):

$$[(1 + i)^n (i)] / [(1 + i)^n - 1]$$

Where
i = discount rate (4 percent)
n = project life (at least 3 years see specific project criteria for default maximums)

The discount rate of 4 percent reflects the prevailing earning potential for state funds that could reasonably be expected by investing state funds in various financial instruments over the length of the minimum project life of Carl Moyer Program projects.

Table B-1 in Appendix B lists the CRF for various project lives using a discount rate of 4 percent. Use the result from formula C-13 to complete formula C-12 to determine the annualized cost of a project.

2. Calculating the Incremental Cost

In previous guidelines, incremental cost was determined by calculating the difference in cost between the new reduced technology and the baseline technology, making it necessary for the applicant to receive quotes for both the reduced and the baseline technologies. ARB staff decided to streamline this process by applying maximum eligible percent funding amounts to define incremental cost, eliminating the need to receive quotes for the baseline technology. An applicant would only need to provide an estimate of the cost of the reduced technology. Therefore, the incremental cost is determined by multiplying the cost of the reduced technology by the maximum eligible percent funding amount (from applicable chapter), as described in formula C-14 below.

Formula C-14: Incremental Cost ($):

*Cost of Reduced Technology ($) * Maximum Eligible Percent Funding Amount*

Generally the cost of the baseline vehicle for a new purchase is assumed to be a certain percentage of the cost of a new vehicle meeting reduced emissions from the standard. The cost of the baseline technology for a repower is assumed to be a percentage of the new engine. For retrofits, there is no baseline technology cost; hence the entire cost of the retrofit may be eligible for funding.

For fleet modernization projects, the incremental cost is determined by adjusting the value given to the vehicle by the National Automotive Dealership Association (N.A.D.A.), as described in formula C-15 below.

Formula C-15: Incremental Cost for Fleet Modernization Projects ($):

When the replacement vehicle is not new:

N.A.D.A value

where the N.A.D.A value is the retail value of the used vehicle * 50 percent.

When the replacement vehicle is new:

*Invoice of the New Vehicle * 50 percent*

Use the results from formula C-14 or C-15 to complete formula C-12 to determine the annualized cost of a project.

List of Formulas

For an easy reference, the necessary formulas to calculate the cost-effectiveness of surplus emission reductions for a project funded through the Carl Moyer Program are provided below.

Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton):

$$\frac{\text{Annualized Cost (\$/yr)}}{\text{Annual Weighted Surplus Emission Reductions (tons/yr)}}$$

Formula C-2: Annual Weighted Surplus Emission Reductions:

NOx reductions (tons/yr) + ROG reductions (tons/yr) + [20 * PM10 reductions (tons/yr)]

Formula C-3: Estimated Annual Emissions by Pollutant (tons/yr):

*Emission Factor or Converted Emission Standard (g/bhp-hr) * Annual Activity * Adjustment Factor(s) * Percent Operation in CA* (ton/907,200g)*

Formula C-4: Estimated Annual Emissions based on hours of Operation (tons/yr):

Emission Factor or Converted Emission Standard (g/bhp-hr) * Horsepower * Load Factor * Activity (hrs/yr) * Percent Operation in CA * ton/907,200g

Formula C-5: Replacement Load Factor:

$$\text{Load Factor}_{\text{baseline}} * \text{hp}_{\text{baseline}} / \text{hp}_{\text{reduced}}$$

Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr):

Emission Factor or Converted Emission Standard (g/bhp-hr) * ECF (hp-hr/gal) * Activity (gal/yr) * Percent Operation in CA * ton/907,200g

Formula C-7: Estimated Annual Emissions based on Fuel Consumed using On-Road Emission Factors (tons/yr):

[On-Road Emission Factor (g/mile)/Unit Conversion Factor (bhp-hr/mile)] * ECF (hp-hr/gal) * Activity (gal/yr) * Percent Operation in CA * ton/907,200g

Formula C-8: Estimated Annual Emissions based on Mileage using Emission Factors (tons/yr):

Emission Factor (g/mile) * Activity (miles/yr) * Percent Operation in CA * ton/907,200g

Formula C-9: Estimated Annual Emissions based on Mileage using Converted Emission Standards (tons/yr):

Converted Emission Standard (g/bhp-hr) * Unit Conversion Factor (bhp-hr/mile) * Activity (miles/yr) * Percent Operation in CA * ton/907,200g

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases:

Annual Emissions for the Baseline Technology –
Annual Emissions for the Reduced Technology

Formula C-11: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Retrofits:

Annual Emissions for the Baseline Technology *
Reduced Technology Verification Percent

Formula C-12: Annualized Cost ($):

CRF * incremental cost ($)

Formula C-13: Capitol Recovery Factor (CRF):

$$[(1 + i)^{n} (i)] / [(1 + i)^{n} - 1]$$

Where i = discount rate (4 percent) and n = project life (at least 3 years see specific project criteria for default maximums)

Formula C-14: Incremental Cost ($):

Cost of Reduced Technology ($) * Maximum Eligible Percent Funding Amount

The above excerpt from the 2008 Carl Moyer Program Guidelines does not contain all the information that is found in the complete 2008 guidelines.

The compete Carl Moyer Program Guidelines can be found at :
http://www.arb.ca.gov/msprog/moyer/2008guideline_updates.htm

Example Locomotive Calculations

This section provides examples of calculations for determining cost-effectiveness of surplus emission reductions for locomotive projects. Example calculation are provided as an illustration only of the methodology for performing different types of locomotive cost effectiveness calculations. Specific projects that are used as an example below do not constitute an additional project type that AQIP demonstration project funds will be allocated toward, the examples below are provided as a reference only. ..

Example 1 – Switch Locomotive Engine Remanufacture Kit (Class 3 Railroad)

A Class 3 railroad operator opts to remanufacture an existing 1971 model year switch locomotive engine with a U.S. EPA-certified Tier 0 Engine Remanufacture Kit. The existing locomotive consumes 40,000 gallons of fuel per year, with 100 percent operation in California. The cost of the remanufacture kit plus installation of the kit costs $400,000. The cost to purchase and install an automatic engine start-stop ILD is $11,000. The railroad company will commit to a 10 year project life. Emission reductions are calculated as follows:

<u>Baseline Technology Information:</u>
- Locomotive model year (application): 1971
- Locomotive emission rate (Table B-18a): 16.36 g/bhp-hr NOx, 1.06 g/bhp-hr ROG, 0.378 g/bhp-hr PM10
- Activity (application): 40,000 gal/year
- Energy consumption factor = 20.8 bhp-hr/gal (Table B-25)

<u>Reduced Technology Information:</u>
- Emission Factors (Table B-18a): 11.84 g/bhp-hr NOx, 1.06 g/bhp-hr ROG, 0.378 g/bhp-hr PM10[1]
- Activity (application): 40,000 gal/year
- Energy consumption factor = 20.8 bhp-hr/gal (Table B-25)
- ILD emission reduction factor (Table B-19): 0.90
- Locomotive project criteria allow for the Carl Moyer Program to pay for up to 85 percent of the remanufacture kit cost and 50 percent of ILD cost

<u>Emission Reduction Calculations:</u>
Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr):

1. Annual NOx baseline technology emissions
   (16.36 g/bhp-hr*40,000 gal/yr*20.8 bhp-hr/gal)*(ton/907,200g) = 15.00 ton/yr NOx
2. Annual NOx reduced technology emissions
   (11.84 g/bhp-hr*40,000 gal/yr*20.8 bhp-hr/gal*0.90)*(ton/907,200g)=9.77 ton/yr NOx
3. Annual ROG baseline technology emissions
   (1.06 g/bhp-hr *40,000 gal/yr*20.8 bhp-hr/gal)*(ton/907,200g) = 0.97 ton/yr ROG
4. Annual ROG reduced technology emissions
   (1.06 g/bhp-hr*40,000 gal/yr*20.8 bhp-hr/gal *0.90)*(ton/907,200g)=0.87 ton/yr ROG
5. Annual combustion PM10 baseline technology
   (0.378 g/bhp-hr*40,000 gal/yr*20.8 bhp-hr/gal)*(ton/907,200g) = 0.347 ton/yr PM10
6. Annual combustion PM10 reduced technology emissions
   (0.378 g/bhp-hr*40,000 gal/yr*20.8 bhp-hr/gal *0.90)*(ton/907,200g)
   = 0.312 ton/yr PM10

[1] For information regarding how to calculate reduced engine emission factors, refer to the Supplemental Documents webpage at: www.arb.ca.gov/msprog/moyer/guidelines/supplemental-docs.htm

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- NOx emission benefits = 15.00 tons/yr – 9.77 tons/yr = 5.23 tons/yr NOx
- ROG emission benefits = 0.97 tons/yr - 0.87 tons/yr = 0.10 tons/yr ROG
- PM10 emission benefits= 0.347 tons/yr - 0.312 tons/yr = 0.035 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

5.23 tons/yr + 0.10 tons/yr + 20(0.035 tons/yr) = 6.02 weighted tons/yr

<u>Annualized Cost:</u>

Project Life: 10 years

CRF (Table B-1): = 0.123

Formula C-14: Incremental Cost

($400,000 * 85 percent) + ($11,000 * 50 percent) = 345,500

Formula C-12: Annualized Cost

0.123 * $345,500 = $42,497/yr

<u>Cost-Effectiveness:</u>

Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton)

($42,497/yr)/(6.02 weighted tons/yr)

= $7,057/tons of weighted surplus emissions reduced

The project cost-effectiveness is below $16,000 per weighted ton of emissions reduced. Therefore, the project qualifies for $305,500 in Carl Moyer Program funding.

Example 2 – Multiple Engine Switcher Purchase (Class 1 Railroad)

A Class 1 railroad operator has the opportunity to purchase an alternative technology switch locomotive. Because this is a multiple engine switcher (Engine Family Number 7NREG0060LOC) with new electronics, a new battery, and other components, the project is evaluated as a new locomotive purchase. Fuel receipts indicate other switch locomotives with the same activity in the rail yard consume 45,000 gallons of fuel per year. The cost of the new alternative technology switcher is $1.2 million. The project life is 10 years. Emission reductions are calculated as follows:

<u>Baseline Technology Information:</u>

- Locomotive model year: none
- Locomotive emission factor (Tier 0, Table B-18a)[2]: 11.84 g/bhp-hr NOx, 1.06 g/bhp-hr ROG, 0.378 g/bhp-hr PM10
- Activity (application): 45,000 gal/year
- Energy consumption factor = 20.8 bhp-hr/gal (Table B-25)

<u>Reduced Technology Information:</u>

- Engine model year: 2007
- Emission factors (Engine Family 7NREG0060LOC)[1]: 2.54 g/bhp-hr NOx, 0.105 g/bhp-hr ROG, 0.060 g/bhp-hr PM10
- Activity (application): 45,000 gal/year

[2] For information regarding how to determine reduced engine emission factors, refer to the Supplemental Documents webpage at: www.arb.ca.gov/msprog/moyer/guidelines/supplemental-docs.htm

- Energy consumption factor = 18.5 bhp-hr/gal (Table B-25)
- Locomotive project criteria allow for the Carl Moyer Program to pay for up to 50 percent of Class 1 railroad alternative switcher locomotive purchase cost

<u>Emission Reduction Calculations:</u>

Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr):

1. Annual NOx baseline technology emissions
   (11.84 g/bhp-hr * 45,000 gal/yr * 20.8 bhp-hr/gal) *(ton/907,200g) = 12.21 ton/yr NOx
2. Annual NOx reduced technology emissions
   (2.54 g/bhp-hr * 45,000 gal/yr * 18.5 bhp-hr/gal) *(ton/907,200g) = 2.33 ton/yr NOx
3. Annual ROG baseline technology emissions
   (1.06 g/bhp-hr * 45,000 gal/yr * 20.8 bhp-hr/gal) *(ton/907,200g) = 1.09 ton/yr ROG
4. Annual ROG reduced technology emissions
   (0.105 g/bhp-hr * 45,000 gal/yr * 18.5 bhp-hr/gal) *(ton/907,200g) = 0.10 ton/yr ROG
5. Annual combustion PM10 baseline technology
   (0.378 g/bhp-hr * 45,000 gal/yr * 20.8 bhp-hr/gal) *(ton/907,200g)=0.390 ton/yr PM10
6. Annual combustion PM10 reduced technology emissions
   (0.060 g/bhp-hr * 45,000 gal/yr * 18.5 bhp-hr/gal) *(ton/907,200g)=0.055 ton/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- Emission benefits NOx = 12.21 tons/yr – 2.33 tons/yr = 9.88 tons/yr NOx
- Emission benefits ROG = 1.09 tons/yr – 0.10 tons/yr = 1.00 tons/yr ROG
- Emission benefits PM10 = 0.390 tons/yr – 0.055 tons/yr = 0.335 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

9.88 tons/yr +1.00 tons/yr + 20(0.335 tons/yr) = 17.59 weighted tons/yr

<u>Annualized Cost:</u>

Project Life: 10 years

CRF (Table B-1): = 0.123

Formula C-14: Incremental Cost

$1,200,000 * 0.50 = $600,000

Formula C-12: Annualized Cost

0.123 * $600,000 = $73,800/yr

<u>Cost-Effectiveness:</u>

Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton)

($73,800/yr)/(17.59 weighted tons/yr)

= $4,197/tons of weighted surplus emissions reduced

The project cost-effectiveness is below $16,000 per weighted ton of emissions reduced. Therefore, the project qualifies for $600,000 in Carl Moyer Program funding.

Example 3 – Idle-Limiting Device Installation (Class 3 Railroad)

A Class 3 railroad wants to purchase and install an AESS ILD on one of its 1970 uncontrolled switch locomotives. Fuel receipts indicate other switch locomotives with the same activity in the rail yard consume 25,000 gallons of fuel per year. The cost to purchase and install the AESS is $14,000. The project life is 3 years. Emission reductions are calculated as follows:

Baseline Technology Information:

- Locomotive model year: 1970
- Locomotive emission rate (uncontrolled, Table B-18): 16.36 g/bhp-hr NOx, 1.06 g/bhp-hr ROG, 0.378 g/bhp-hr PM10
- Activity (application): 25,000 gal/year
- Energy consumption factor = 20.8 bhp-hr/gal (Table B-25)
- ILD emission reduction factor (Table B-19): 0.90
- Locomotive project criteria allow for the Carl Moyer Program to pay for up to 50 percent of ILD cost

Emission Reduction Calculations:

Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr):

1) Annual NOx emission reductions
   (16.36 g/bhp-hr * 25,000 gal/yr * 20.8 bhp-hr/gal) *(ton/907,200g) = 9.38 ton/yr NOx
2) Annual NOx reduced technology emissions
   (16.36 g/bhp-hr*25,000 gal/yr*20.8 bhp-hr/gal*0.90)*(ton/907,200g)=8.44 ton/yr NOx
3) Annual ROG baseline technology emissions
   (1.06 g/bhp-hr * 25,000 gal/yr * 20.8 bhp-hr/gal) *(ton/907,200g) = 0.61 ton/yr ROG
4) Annual ROG reduced technology emissions
   (1.06 g/bhp-hr*25,000 gal/yr*20.8 bhp-hr/gal*0.90)*(ton/907,200g) =0.55 ton/yr ROG
5) Annual combustion PM10 baseline technology
   (0.378 g/bhp-hr * 25,000 gal/yr * 20.8 bhp-hr/gal)*(ton/907,200g) =0.217 ton/yr PM10
6) Annual combustion PM10 reduced technology emissions
   (0.378 g/bhp-hr*25,000 gal/yr*20.8 bhp-hr/gal*0.90)*(ton/907,200g)=0.195ton/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- Emission benefits NOx   = 9.38 tons/yr – 8.44 tons/yr   = 0.94 tons/yr NOx
- Emission benefits ROG = 0.61 tons/yr – 0.55 tons/yr   = 0.06 tons/yr ROG
- Emission benefits PM10 = 0.217 tons/yr – 0.195 tons/yr   = 0.022 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

0.94 tons/yr +0.06 tons/yr + 20(0.022 tons/yr) = 1.43 weighted tons/yr

Annualized Cost:

Project Life: 3 years

CRF (Table B-1):   = 0.360

Formula C-14: Incremental Cost

$14,000 * 0.50   = $7,000

Formula C-12: Annualized Cost

0.360 * $7,000   = $2,520/yr

Cost-Effectiveness:

Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton)

($2,520/yr)/(1.43 weighted tons/yr)

= **$1,760/tons of weighted surplus emissions reduced**

The project cost-effectiveness is below $16,000 per weighted ton of emissions reduced. Therefore, the project qualifies for $7,000 in Carl Moyer Program funding.